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(54) **Water vapor exchange system**

(57) Water vapor is directly exchanged from one gas stream to another by means of a gas impervious water vapour transporting membrane positioned between the two streams. Water vapor can be transported from a lower pressure to a higher pressure stream as long as the partial pressure of the water vapor is higher in the transferor stream than in the transferee stream.

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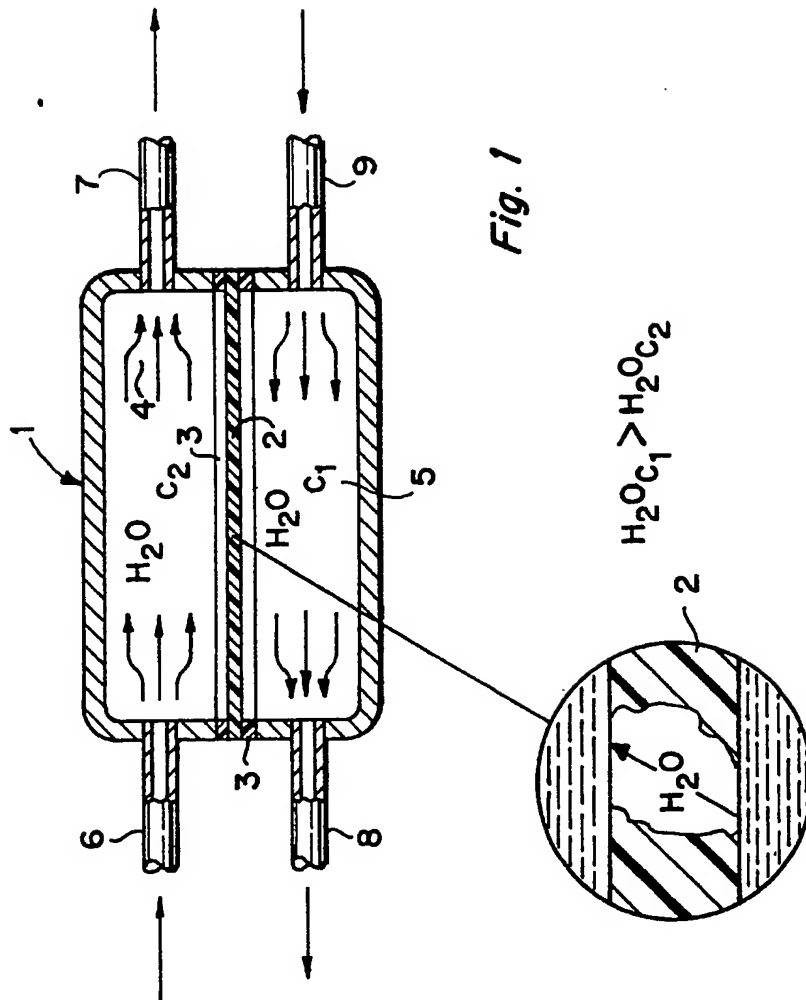


Fig. 1

SPECIFICATION

Water vapour exchange system

5 This invention relates to a process and apparatus for directly transferring water vapor from one gaseous stream to another without condensing and re-vaporizing and, more particularly without mixing gaseous streams at different pressures.

10 Humidification of a gaseous stream by the extraction of water vapor from another stream has conventionally been achieved by first condensing the water vapor from one stream, pumping the condensate to the pressure of the second stream, if the second
15 stream is at a higher total pressure, re-vaporizing the water by the addition of heat and injecting it into the second stream. It is obvious simply from the description of the conventional process that it is energy intensive because it involves condensing, pumping
20 and evaporating steps and requires costly equipment such as condensers, pumps and vaporizers. A need therefore exists for an apparatus and process which allows the direct exchange of water vapor from one stream to a stream of higher overall
25 pressure without the intermediate condensing, pressurizing and evaporating steps.

We have found that a direct exchange of water vapor from one stream to another stream, for humidifying or drying purposes, may be achieved
30 simply and effectively by means of an arrangement in which the two streams are separated by means of a gas impervious polymeric membrane which permits transport of water vapor but separates the gaseous streams. Direct water transport across the
35 membrane can be achieved from a lower pressure to a higher pressure stream as long as the partial water vapor pressure of the transferor stream is higher than that of the transferee stream even though the total pressure of the transferee stream may be
40 higher than that of the transferor stream. Polymeric membranes such as cellophane or perfluorinated carbon membranes such as the ones sold by DuPont under its trade designation Nafion may be utilized to permit direct water vapor transfer between the two
45 streams.

The present invention attempts to provide a process and apparatus for the direct transfer of water vapor between two streams.

The present invention also attempts to provide
50 direct transfer of the water vapor from one stream to a second stream even though the overall pressure of the second stream is higher than that of the stream from which the water vapor is to be transferred.

Another objective of the invention is to attempt to
55 provide direct transfer of water vapor between one gaseous stream and another gaseous stream while maintaining the gaseous stream physically separated.

According to the present invention there is provided a process for directly transferring water vapor
60 between two gaseous streams comprising the steps of:

a) flowing two gaseous streams over opposite surfaces of a gas impervious water vapor transport-
65 ing membrane separating said streams

b) one of said streams having a higher water vapor partial pressure than the other whereby water vapor is transported from said one stream to said other stream.

70 The present invention also provides a water exchange apparatus for directly transferring water vapor between two individual gaseous streams comprising:

a) a housing

75 b) a gas impervious membrane separating said housing into two chambers

c) said gas impervious membrane being capable of transporting water from one side to the other

d) means for introducing individual gaseous
80 streams to said chambers

e) one of said streams having a higher water vapor partial pressure than the other whereby water vapor is transported to the stream with the lower water vapor partial pressure independent of the relative
85 total pressures of said gaseous streams.

Thus the invention provides a process and apparatus in which two gaseous streams, between which water vapor is to be transferred, are caused to flow and come in contact with opposite sides of a water
90 vapor transport membrane. The membrane physically separates the streams but permits transport of water vapor from the stream which has the higher water vapor partial pressure even though the overall pressure of the recipient stream may be greater than
95 that of the stream with the higher water vapor partial pressure. The membrane may be any one of a variety of membranes capable of transporting water vapor such as cellophane, perfluorinated fluorocarbon membranes of the type sold by DuPont under its
100 trade designation Nafion. Preferably, the two gaseous streams move through the humidifier in a counterflow arrangement as this is much more effective in transferring the water vapor which has been brought across the membrane into the trans-
105 feree stream.

The present invention will be further described, by way of example only with reference to the accompanying drawings, in which is a sectional view of a structure for the direct transfer of water vapor from
110 one gaseous stream to another.

The Figure shows a sectional view of a two-chamber humidifier comprising a metallic housing 1 separated by a water vapor transport membrane 2 and a suitable gasket 3 into gas transport chambers
115 4 and 5. The housing, may be fabricated of any suitable material such as aluminum, steel, plastic, etc. It includes inlet and outlet conduits 6, 7, 8 and 9 through which the two gaseous streams are introduced and removed from the chambers. As shown in
120 the expanded portion of the vapor transport membrane 2, the membrane, which may be of cellophane or a fluorocarbon perfluorinated polymer such as DuPont Nafion 1200, is characterized by the fact that it is impervious to liquid or gaseous hydraulic flow
125 but will permit the transport of water in the form of vapor thereby permitting transport of water vapor from one gaseous stream to the other without intermixing of the gaseous streams.

The exchange of water vapor between the two
130 streams by means of transport through such mem-

branes not only is energy efficient because of the direct exchange of the water vapor between the streams but is also effective because there is no need to equilibrate the stream pressures prior to vapor transport. That is vapor transport may take place even though the overall or total pressures of the gaseous streams on opposite sides of the membranes are different since the membrane will withstand both high temperatures, 300°F or so, as well as substantial pressure differentials.

That is, water vapor can be transferred from one gas stream to the other even though the gas stream to which the water vapor is transferred has a higher overall pressure than the gas stream from which the water vapor comes as long as the partial pressure of the water vapor in the transferor gaseous stream exceeds that of the recipient or transferee gaseous stream. The water vapor transport across such a membrane in terms of water mols per hour is a function of the log mean concentration difference of the water vapor partial pressure on opposite sides of the membrane. Specifically, the water vapor transport is defined by the following equation:

$$N_{H_2O} = KA(\Delta C_{inM})$$

Where:

N_{H_2O} is the flow rate of water, mol/hr

K is the mass transport coefficient, Ft/hr

A is the membrane area Ft²

ΔC_{inM} is the log mean concentration difference across the membrane in mol/ft³.

It can be seen, therefore, that although the overall pressure of the two gas streams may be such that one the receiving stream has a higher overall pressure, water vapor transport will take place as long as the partial pressure of the water vapor is greater in the transferor stream.

It is apparent, therefore, that the arrangement described above is effective in transferring water vapor from one gaseous stream to another gaseous stream in a direct fashion without having to condense the water, pump it and revaporize it before transferring it to the recipient stream. Furthermore, such an arrangement is extremely effective because it avoids the need for steam pressure matching between the different gaseous streams, it avoids the need for equipment for condensing, pressurizing and evaporating the water in order to transfer it between the two streams. A very effective, inexpensive arrangement for humidifying a gaseous stream by transferring gaseous vapor between one stream and another has been provided.

While the instant invention has been shown in connection with certain preferred embodiments thereof and certain preferred processes for achieving the end result, the invention is by no means limited to these embodiments or these procedural sequences since other modifications of the instrumentalities employed and of the steps of the

process may be made still fall within the scope of the invention. It is contemplated by the appended claims to cover any such modifications that fall within the true scope and spirit of this invention.

CLAIMS

1. A process for directly transferring water vapor between two gaseous streams comprising the steps of:

a) flowing two gaseous streams over opposite surfaces of a gas impervious water vapor transporting membrane separating said streams,
b) one of said streams having a higher water vapor partial pressure than the other whereby water vapor is transported from said one stream to said other streams.

2. A process as claimed in Claim 1 whereby water vapor transport takes place from a gaseous stream having a lower overall pressure than the stream to which the water vapor is transported.

3. The process as claimed in Claim 1 or Claim 2 wherein the gaseous streams are counterflowed over opposite surfaces of said membrane.

4. A water exchange apparatus for directly transferring water vapor between two individual gaseous streams comprising:

a) a housing,
b) a gas impervious membrane separating said housing into two chambers,
c) said gas impervious membrane being capable of transporting water from one side to the other,
d) means for introducing individual gaseous streams to said chambers
e) one of said streams having a higher water vapor partial pressure than the other whereby water vapor is transported to the stream with the lower water vapor partial pressure independent of the relative total pressures of said gaseous streams

5. Apparatus as claimed in Claim 4 wherein said means to introduce the individual gaseous streams to said chamber produces counterflow of said gaseous streams with respect to said membrane.

6. A process as claimed in Claim 1 substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

7. Apparatus as claimed in Claim 4 substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.